

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY)		2. REPORT TYPE Technical Papers		3. DATES COVERED (From - To)	
<div style="border: 1px solid black; border-radius: 50%; padding: 20px; text-align: center;"> <p>Please see attached</p> </div>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER 1011	
				5e. TASK NUMBER CAGE	
				5f. WORK UNIT NUMBER 346161	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				8. PERFORMING ORGANIZATION REPORT	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S NUMBER(S) <i>Please see attached</i>	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
20030205 278					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT A	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Leilani Richardson
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code) (661) 275-5015

10 HCA 95

MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (STINFO)

19 May 2001

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2001-145**
Rusty Blanski, Shawn Phillips, "Status of the Air Force Solid Rocket Motor Insulation Program"

50th Annual JANNAF Propulsion Conference
(Salt Lake City, UT, 11-13 July 2001) (Deadline: PAST DUE!)

(Statement A)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.

Comments: _____

Signature _____

Date _____

2. This request has been reviewed by the Public Affairs Office for: a.) appropriateness for public release and/or b) possible higher headquarters review.

Comments: _____

Signature _____

Date _____

3. This request has been reviewed by the STINFO for: a.) changes if approved as amended, b) appropriateness of references, if applicable; and c.) format and completion of meeting clearance form if required

Comments: _____

Signature _____

Date _____

4. This request has been reviewed by PR for: a.) technical accuracy, b.) appropriateness for audience, c.) appropriateness of distribution statement, d.) technical sensitivity and economic sensitivity, e.) military/national critical technology, and f.) data rights and patentability

Comments: _____

APPROVED/APPROVED AS AMENDED/DISAPPROVED

PHILIP A. KESSEL

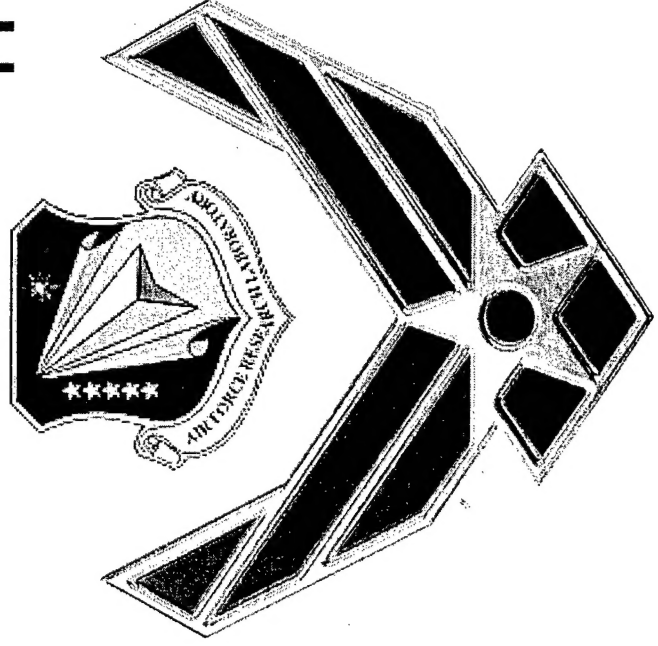
Date

Technical Advisor

Space and Missile Propulsion Division

Status of the Air Force Solid Rocket Motor Insulation Program

11 July 2001



Dr. Rusty Blanski

AFRL/PRSM

rusty.blanski@edwards.af.mil



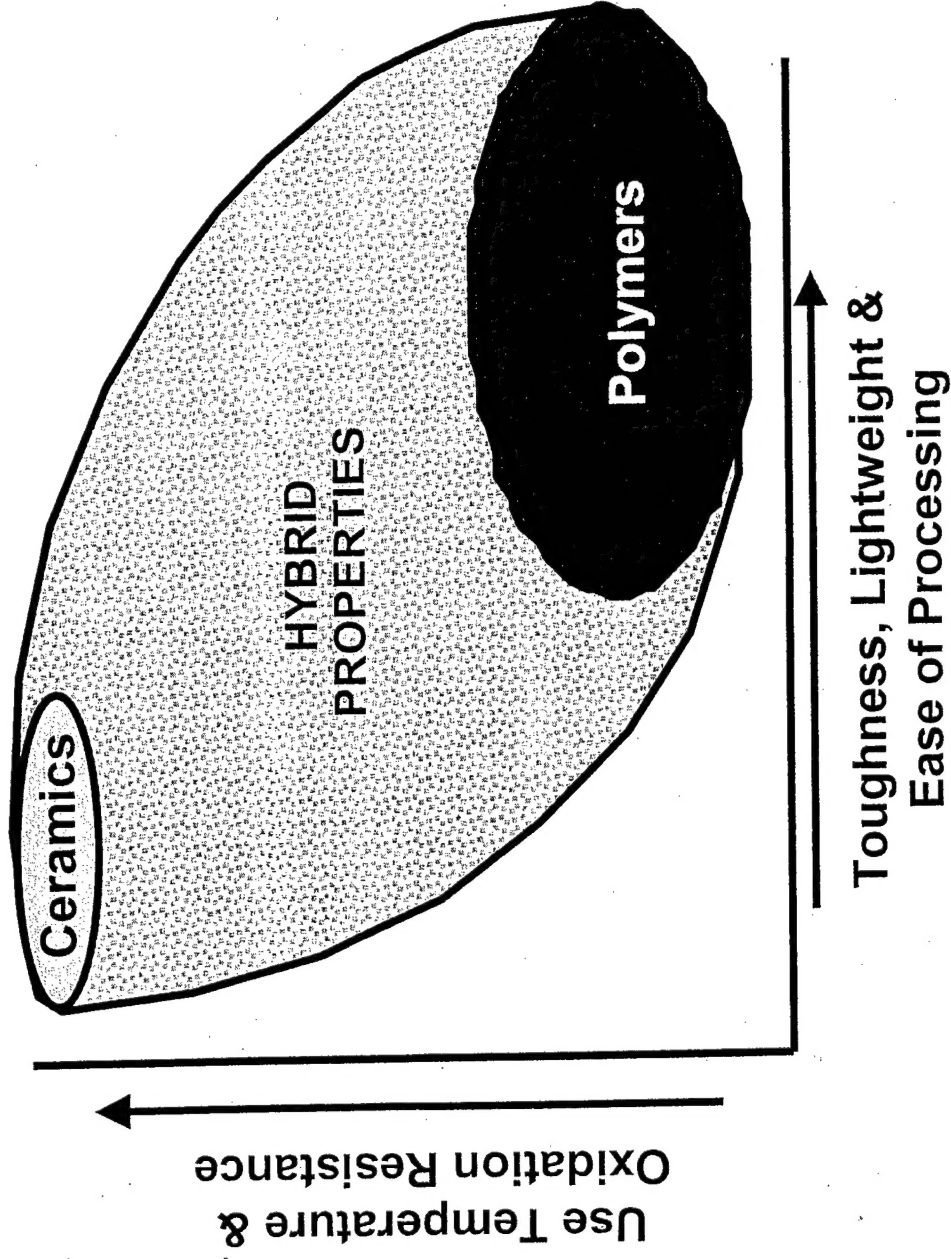
Objectives



- Introduction
- History of our SRM program: Early Work
- In-House efforts
- POSS in EPDM Results
- Future of the Program



Propulsion (Air Force) Technology is Limited by Material Properties

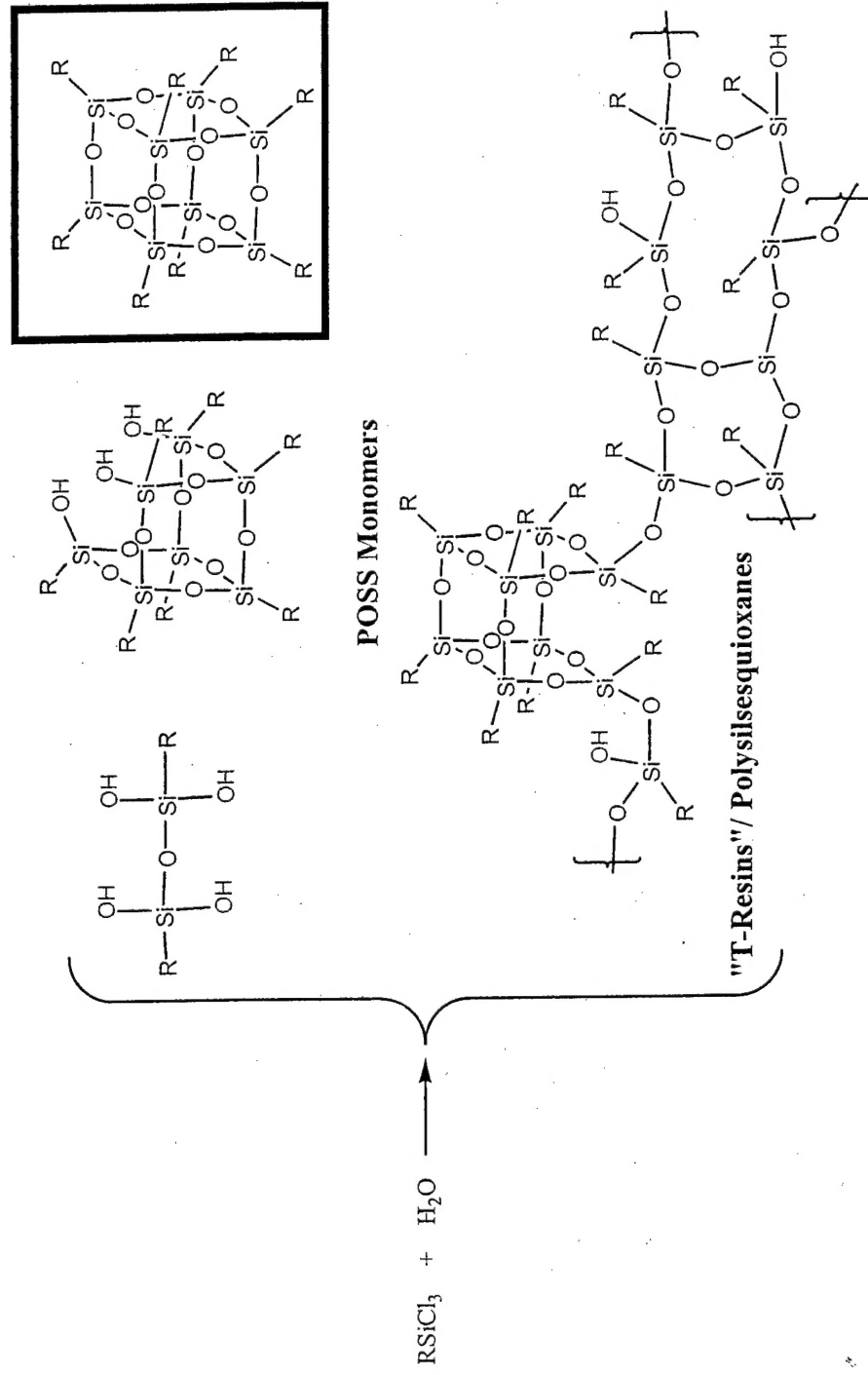


• Hybrid plastics can bridge the barrier between ceramics and polymers



POSS

Polyhedral OligoMeric Silsequioxane



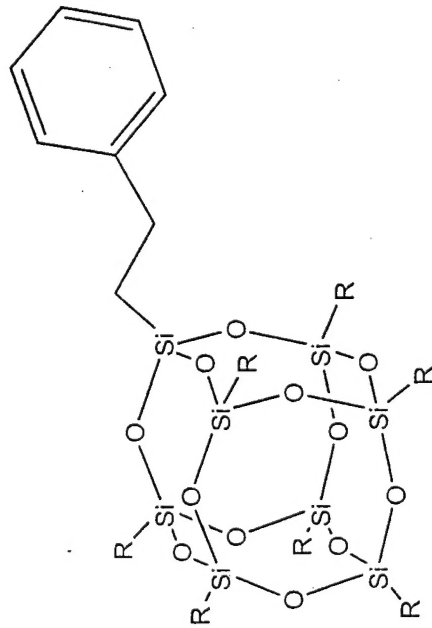
- The maximization of property enhancements in polymers results from interaction at the nano-level (Edwards AFRL/PRSM ----> POSS monomers)⁴



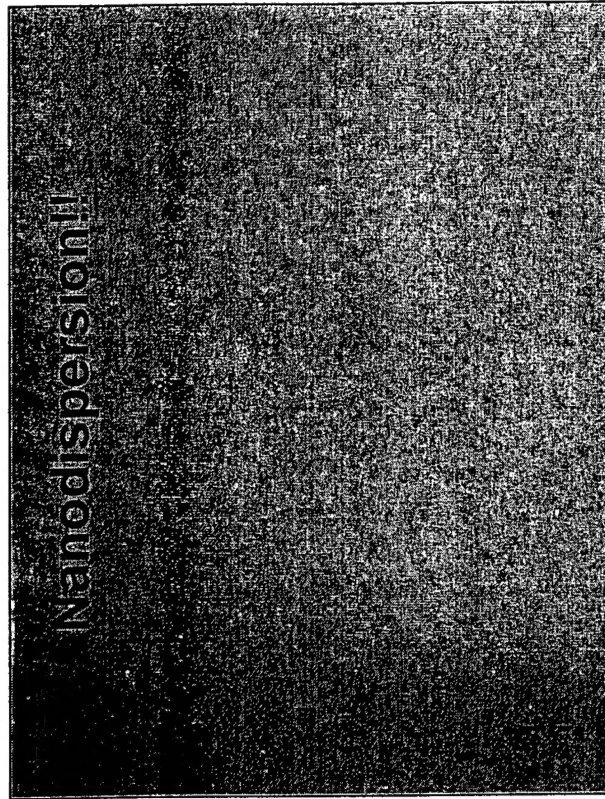
POSS-Polymer Blends

Miscibility Demonstrated

50 wt % Phenethyl₈T₈ in 2 million mol. wt. Polystyrene



R = Phenethyl



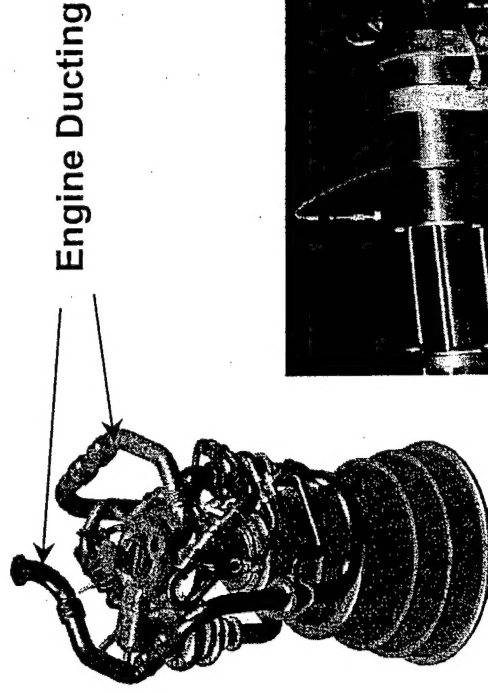
- Catalytic hydrogenation of Styryl₈T₈
- No POSS crystallites by SEM or X-ray!!



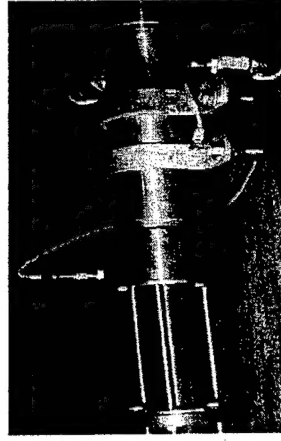
Versatility of POSS Blends and Lubricants



Liquid Rocket Engines



Polymer Tube/Case Hot Gas Burst Tester

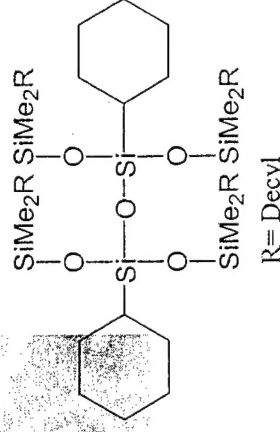
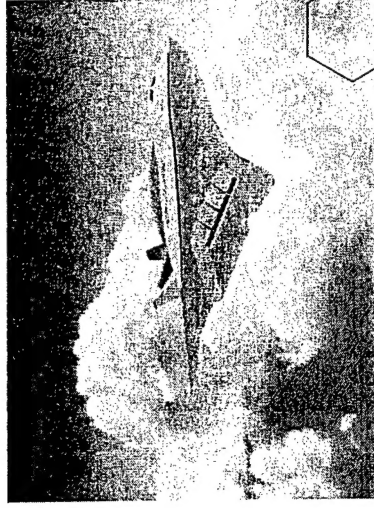


Plastic Engine Ducting (SSME)

- 80% duct weight decrease
- 15% upper stage thrust-to-weight increase

3 candidates selected, SBIR, DUS&T

Lubricants



Lubricants for Turbine Engines

- Demonstrated to be pourable between -40°C and 200°C

"pourable" is
one word

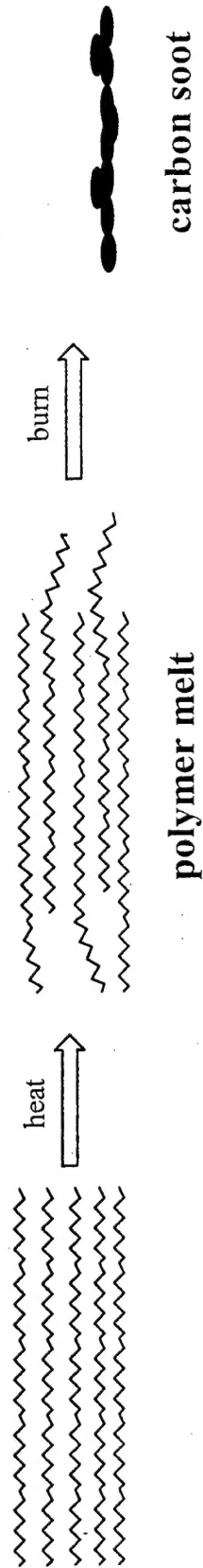
Higher Temperature Studies underway (PRTM)
6



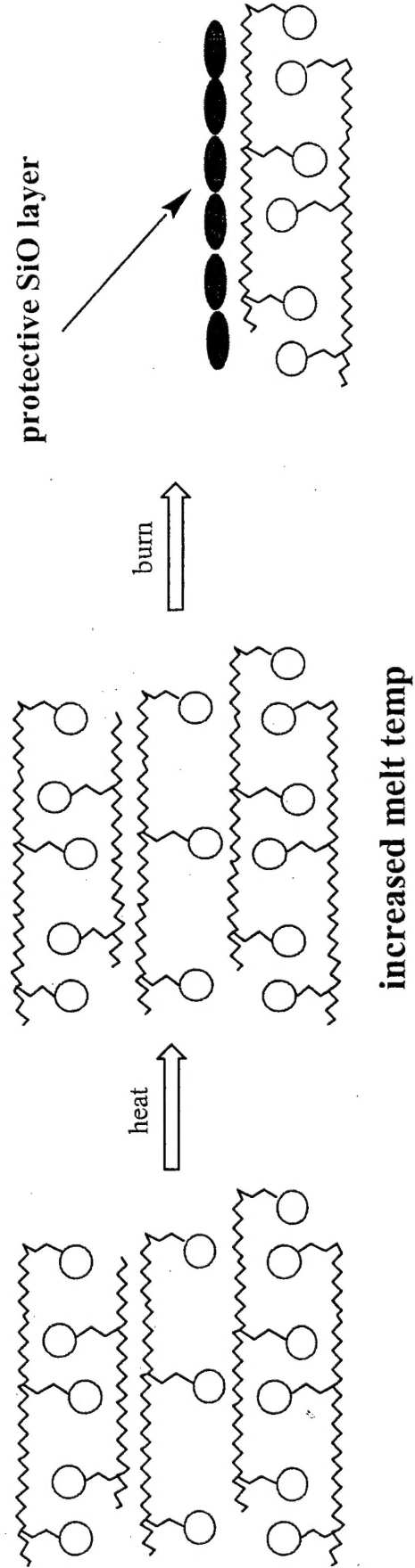
POSS for Ablative Materials



Traditional Polymer



POSS Polymer





Solid Propellant Insulation Program

POSS- Polymers



POSS-Polymer Insulation - Advantages:

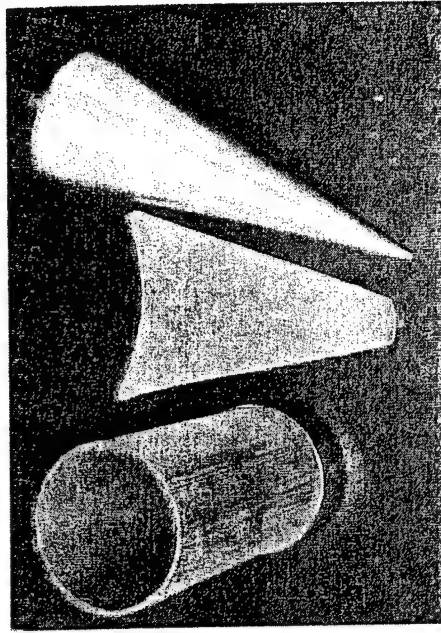
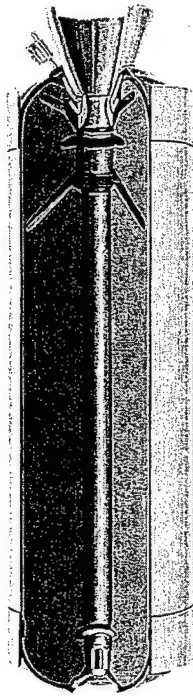
- High loadings of POSS can be incorporated without embrittlement
- Si to O ratio is 1:1.5, proven to oxidize up to 1:2 (SiO₂)
- Tailorability of POSS monomers improve physical/mechanical properties
- Capabilities for Large and Small scale testing (Hybrid Plastics)



Solid Propellant Insulation Program

Project Goals 6.2 (IHPRPT)

Case Insulation



POSS-Insulation Sample

**Goal: 50% Lower Erosion of Insulation (44 % weight reduction,
7.4% booster payload increase) – Phase III IHPRPT**

Objective: Development of Ceramic Forming Polymer



Solid Propellant Insulation Program

In-House Project History

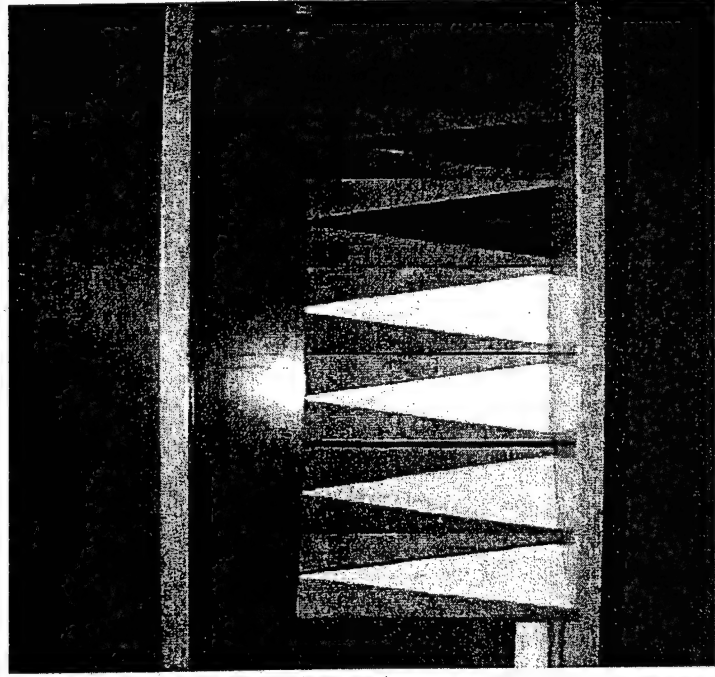


- 1992: Flame testing performed on POSS-PDMS bead polymers. Potential for SRM insulation recognized
- 1994-1998: 4" Pi-K motor testing begun. Due to equipment limitations, a two dimensional test was designed.
- 1999- present: 3-dimensional cone testing capability acquired. Polymer blending equipment and 24 ton press acquired. Firings begun.



Solid Propellant Insulation Program

In-House Project History 1994-1998



2-D pizza wedges
glued into $\frac{1}{2}$ cones

- Sample preparation was difficult: dissolve POSS and polymer in solvent, evaporate and press into wedge in small press
- Glue sample and standard into test bed ($\frac{1}{2}$ cone) and fasten together
- Samples: Pebax, BMI, Parmax, Starfire w/mat



Solid Propellant Insulation Program

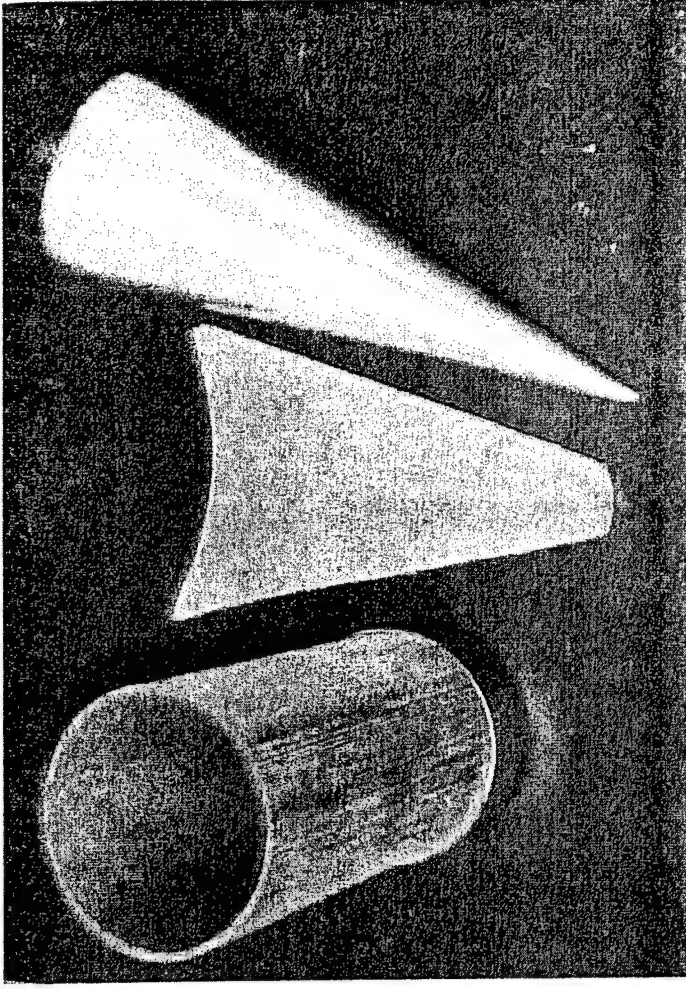
In-House Project History 1999-Present



- 3-dimensional testing capability realized

- Sample preparation was streamlined: POSS is blended into polymer with standard industrial blending equipment (Brabender Mixer) and pressed into Large Pizza wedge (24 ton Press)

- Glue sample and standard into cone



Cone, Pizza Wedge and Jig to set wedges in cone



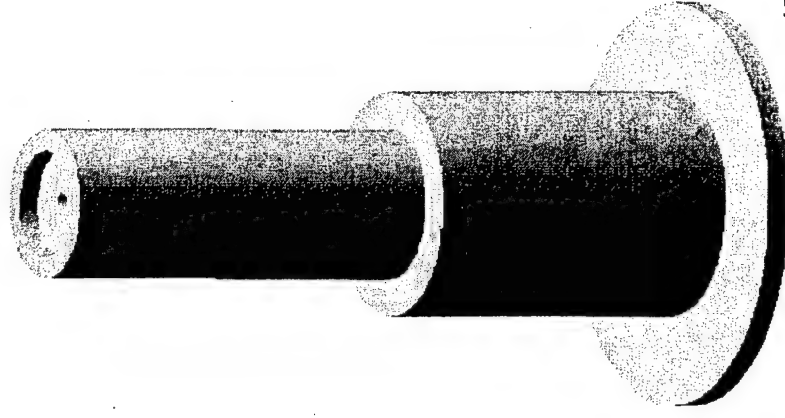
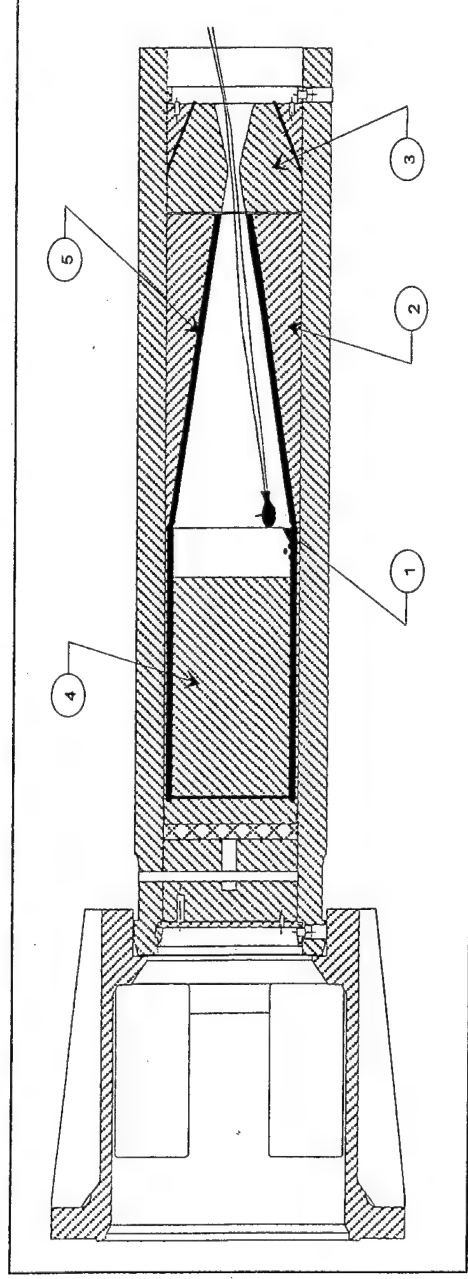
Solid Propellant Insulation Program

In-House Low Cost Screening of New Materials



Present Capabilities:

- Test facilities developed at Edwards AFRL (4" Pi-K Motor)
- Only 100 g of material needed (down from 5 Kg)
- Cost (synthesis, part fabrication, ablation test, analysis) reduced to ~1K!!
- Rapid testing of 5-6 samples per day.





In-House SRM Insulation Testing

Interdisciplinary Team Effort



Many Diverse Skills at AFRL Come Together:

- Phenolic cone Fabrication: Machine Shop
- Pi-K Motor preparation: Propellants Branch
- Pi-K Motor Cutting: Machine Shop
- Sample Cone Preparation: Polymer working Group
- Sample Firing: Propellants Branch
- Sample Analysis: Polymer Working Group (measurements) and Motors Branch (mass flux conversion)

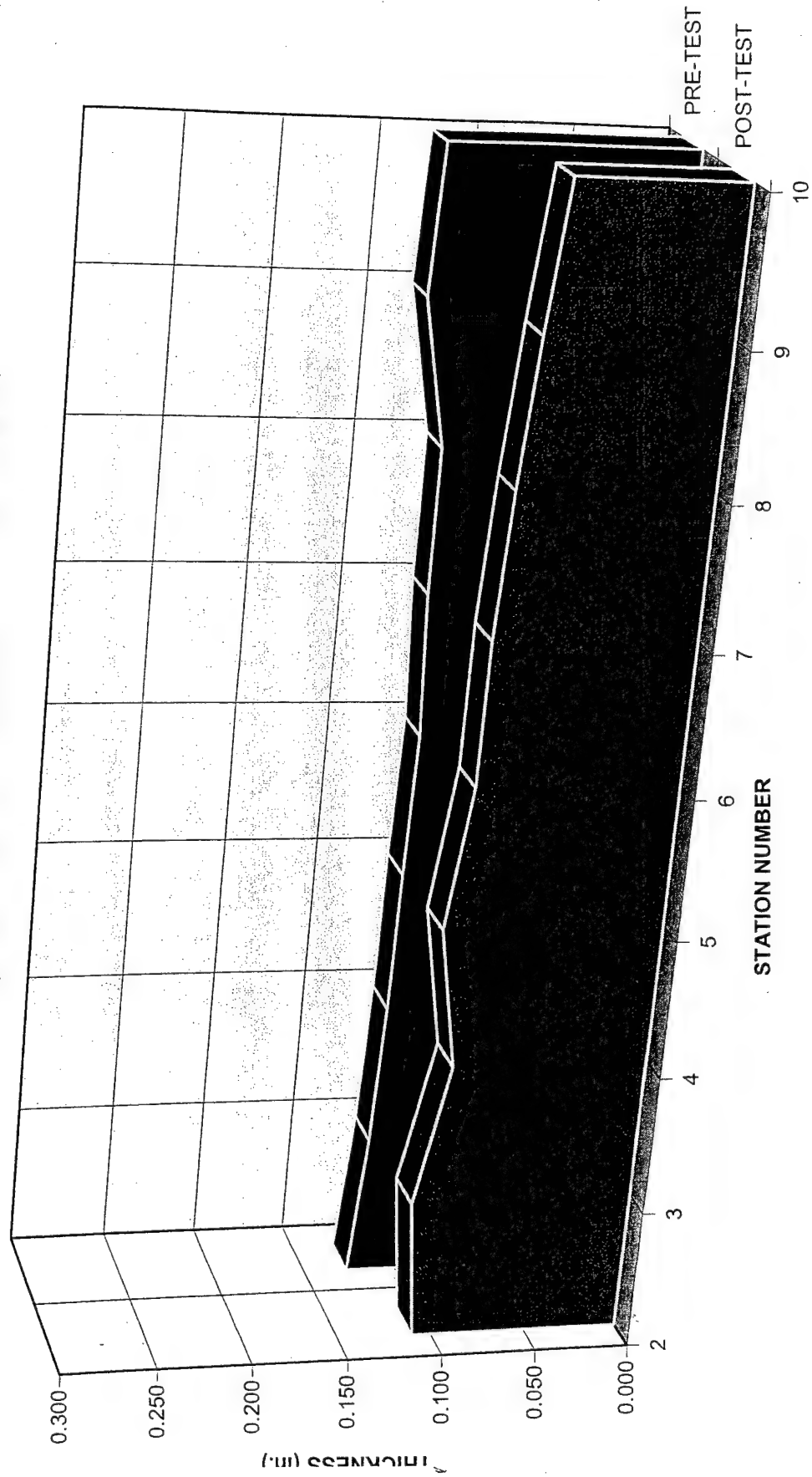


In-House SRM Insulation Testing

Low Cost Screening of New Materials



CHAR-063 ABLATION (S10 - EPDM / Kevlar STANDARD)



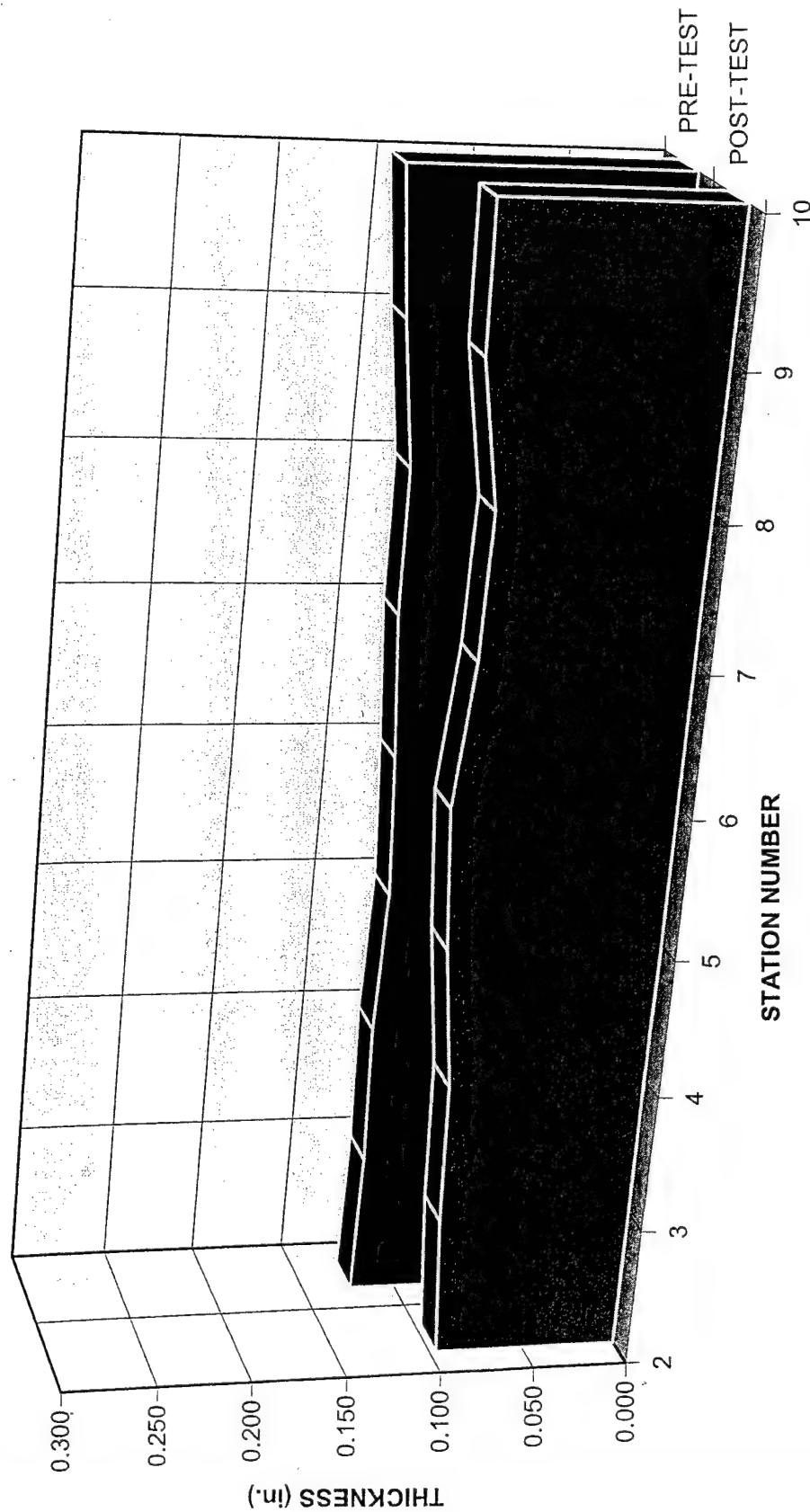


In-House SRM Insulation Testing

Low Cost Screening of New Materials



CHAR-063 ABLATION (T10 - EPDM/V₈T₈)





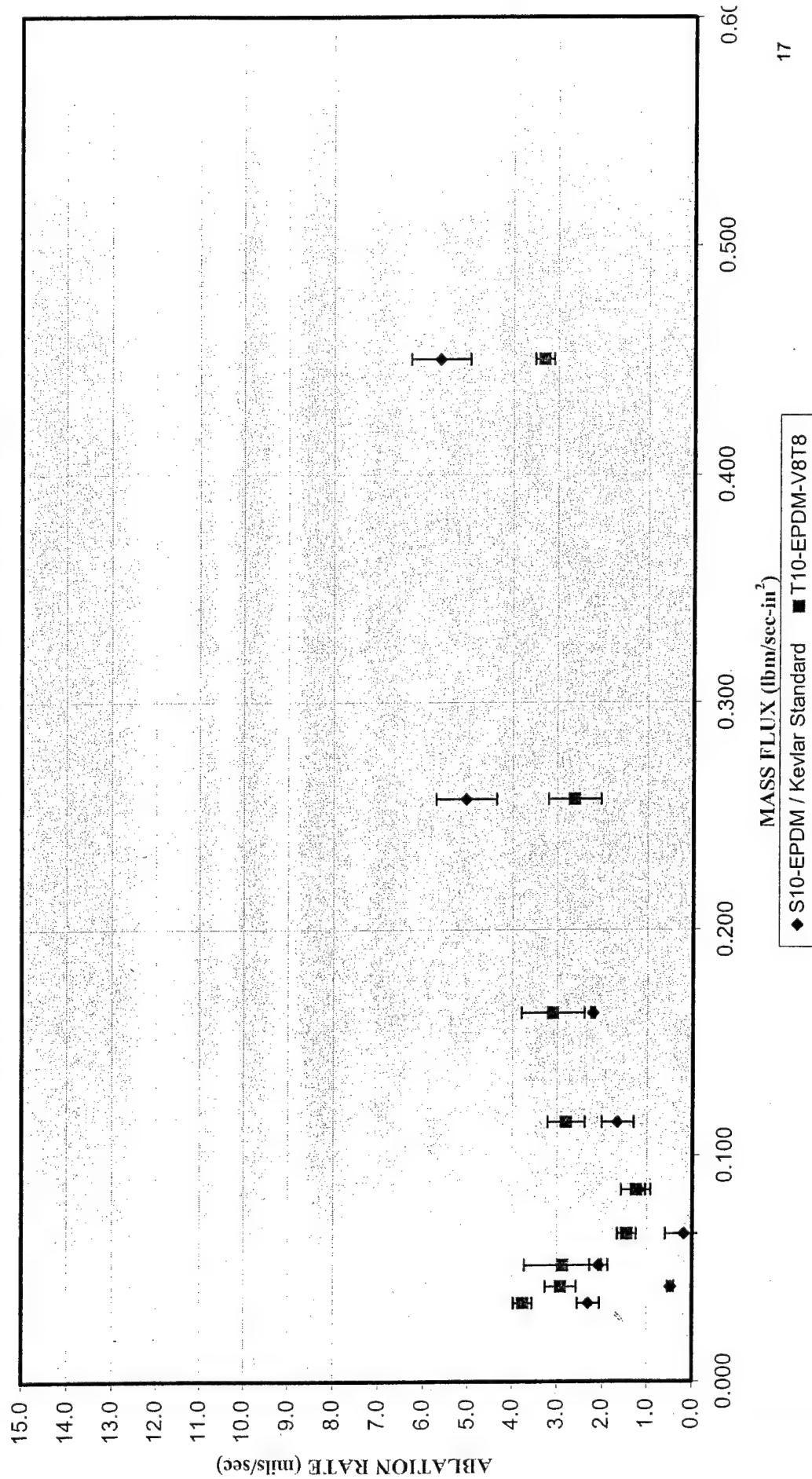
In-House SRM Insulation Testing

Ablation Rate Decreased when Using POSS



CHAR-063 ABLATION RATE

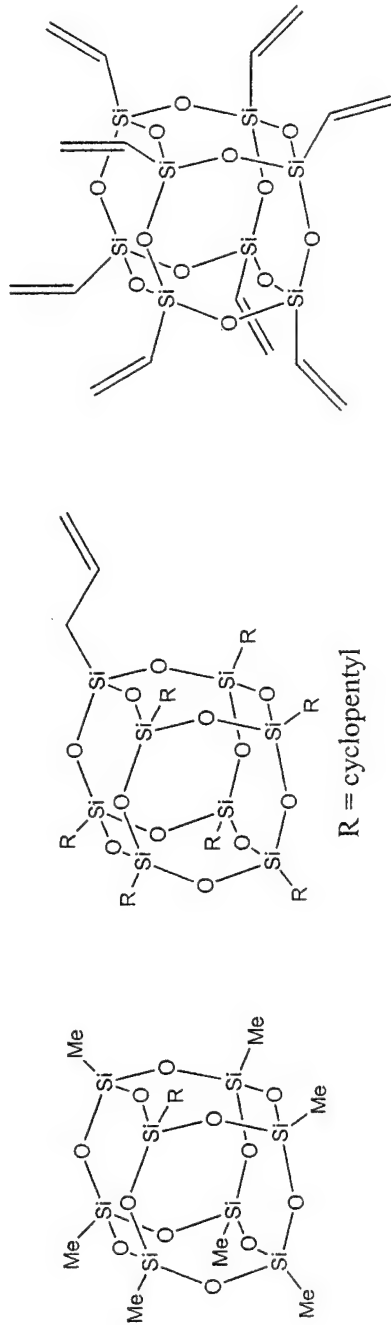
EPDM-Kevlar STANDARD (S10) / EPDM-V₈T₈ (T10)





SRM Insulation Testing Program

Comparisons of POSS in EPDM

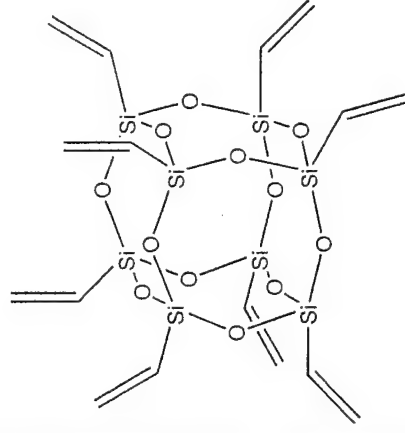


At 50 wt% loadings relative to a proprietary baseline material

Hardness:	15%↑	no change	17%↑
Tensile:	5%↓	27%↓	1%↓
Elongation:	no change	no change	no change
Viscosity:	35%↓	21%↓	36%↓
Density:	15%↑	3%↓	12%↑



A black and white photograph of a mechanical device, likely a vacuum furnace, with three large, dark, conical components labeled A, B, and C. The device is mounted on a base with various pipes and valves. The background is dark and textured.

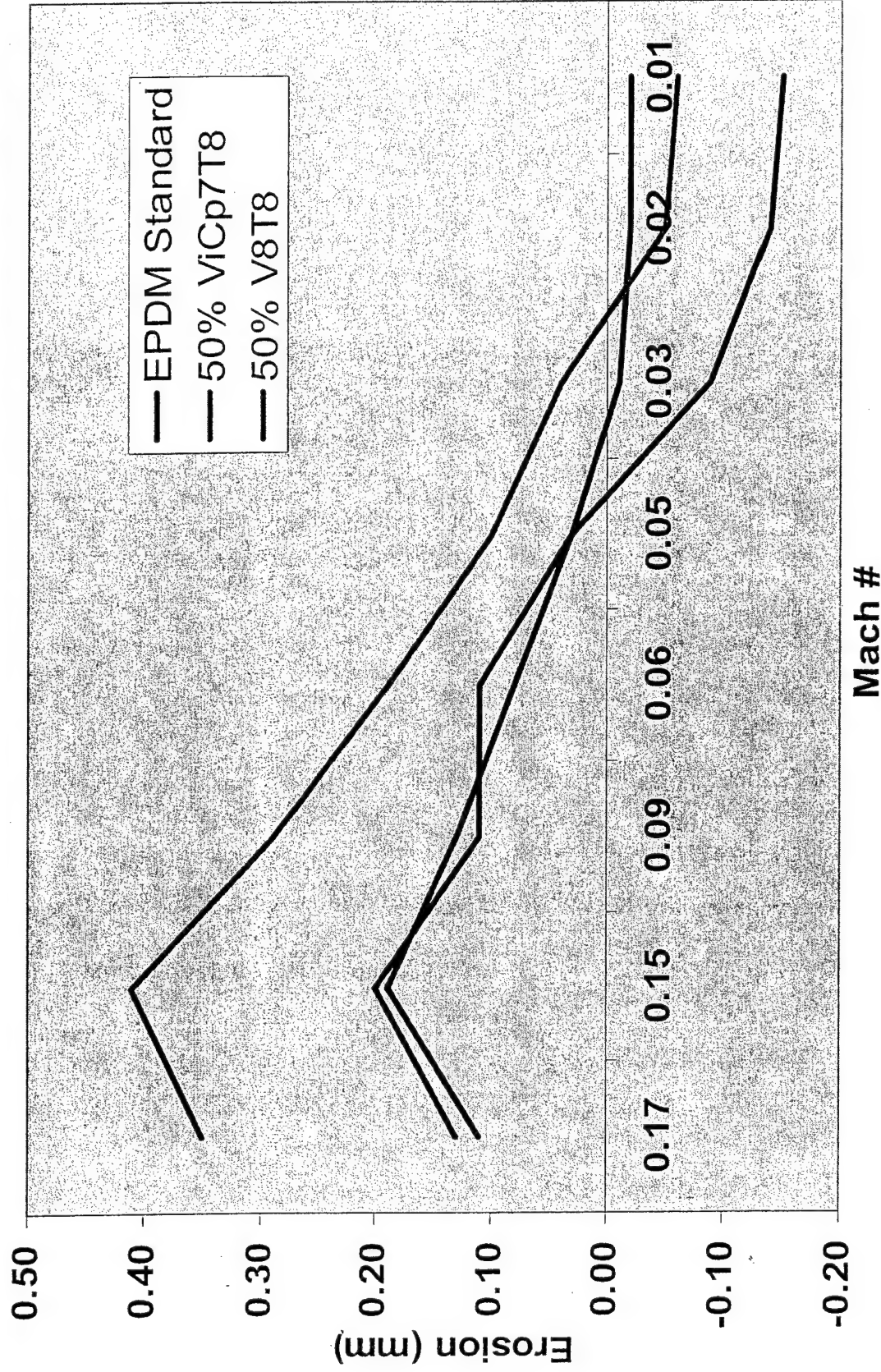


- A) Insulation containing POSS monomers**
- B) Convergent Cone**
- C) Convergent Cone + Insulation**



SRM Insulation Testing Program

Convergent Cone SRM Insulation Tests



Negative numbers represent formation of structural char



SRM Insulation Project

What Comes Next?



- More detailed physical testing of insulation
- Multiple sample cone tests
- 50 Firings Planned for FY '02



SRM Insulation Project

Multiple sample/cone



- Presently we are running the tests with two wedges in the cone: a standard and a test sample
- After the test, the cone is cut in half and measurements are taken
- It may be possible to glue in four samples/cone and still get accurate data (3 samples/1 standard)
- Working out the Logistics of multiple samples and Initial Testing is underway
- Payoff- TRIPLING OF SAMPLE OUTPUT



SRM Insulation Project

Future testing



- **Thermal Property testing**
 - - density
 - - specific heat
 - - thermal conductivity
- **SEM analysis before and after**
- **Char analysis (elemental analysis)**



Conclusions



- We have all the equipment we need for the rapid testing of Solid Rocket Motor insulation
- Initial Testing in the In-House Pi-K motor tests are promising
- Initial Testing with our Partner on a larger scale also looks promising
- Plans for Future Work (multiple samples, physical testing, sample firings) are underway



In-House SRM Insulation Testing

Acknowledgements



- Mr. Hieu Nguyen (Firing Engineer; Sample Analysis)
- Dr. Tom Hawkins and Greg Warmouth (Motor Firings)
- Mr. Phil Counts (Machine Shop)
- Mr. Pat Ruth (Sample Preparation, measurement)
- Dr. Steve Svejda and Shawn Phillips (Moral Support)

Dr. S.